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A LITERATURE REVIEW ON THE EFFECTS OF THE USE OF GRAPHIC CALCULATORS IN COLLEGE ALGEBRA COURSES

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ABSTRACT

College algebra has been ignored in previous math research studies even if it is the first official college level math for most students in their total educational programs. The lack of research has created a significant gap in knowledge on the application of graphic calculators and role of this technological tool in the college math curriculum and classroom. College algebra students face the one of the highest failure rates in the U.S. The purpose of this literature review was to explore the impact graphic calculators had on college students' final grade. Specifically, the researcher focused on the effect of graphic calculators on student performance, motivation, and satisfaction. The theoretical framework comprised of two prongs: constructivist theory and technology-assisted instruction theory. Using these two theories, the researcher reviewed and discussed the theoretical based literature and the evidence-based literature on constructivist approaches to learning that lend to improved student performance, student motivation, and student satisfaction. The researcher then reviewed and discussed the theoretical based literature and the evidence-based literature on technology-assisted approaches to learning in general that lend to improved student performance, student motivation, and student satisfaction. The researcher concluded the review with a discussion of the evidence-based literature focused on the use of the graphic calculator and its application in the math classroom in particular.

KEYWORDS: graphic calculator, teaching and learning strategies, post-secondary education, college grades, student satisfaction and motivation.

1. INTRODUCTION:

In previous math research studies, college algebra has largely been ignored despite the fact that it is the first official college level math for most students in their total educational programs (Dewey et al., 2009). This lack of research has created a significant gap in knowledge on the application of graphic calculators and role of this technological tool in the college math curriculum and classroom. In addition, across the United States, college algebra is a math course in which students experience the highest degree of failure rate, which results in second or third attempts by students to pass the class (Dewey et al., 2009). Critical topics and competencies in college algebra such as transformations on mathematical functions and properties of rational functions and their asymptotes deserve the focus of this research project. The research on these specific math topics has virtually been ignored at this point in time. In this literature review, the purpose is to describe the current literature about the impact graphic calculators had on college students' final grade.

To accomplish this, the researcher focused on the effect of graphic calculators on student performance, motivation, and satisfaction and conducted a literature review to identify a theoretical framework comprised of two prongs: constructivist theory and technology-assisted instruction theory. Using these two theories, the researcher reviewed and discussed the theoretical based literature and the evidence-based literature on constructivist approaches to learning that lend to improved student performance, student motivation, and student satisfaction. The researcher then reviewed and discussed the theoretical based literature and the evidence-based literature on technology-assisted approaches to learning in general that lend to improved student performance, student motivation, and student satisfaction. The researcher concluded the review with a discussion of the evidence-based literature focused on the use of the graphic calculator and its application in the math classroom in particular.

1.1. Search Strategy:

To complete the literature review, the researcher accessed databases including Academic Search Complete, Education Resources Information Center (ERIC), Education Full Text, Education Source, Educators Reference Complete/Gales, ProQuest Dissertations, and Applied Science & Technology Source. Keywords used included the following: *graphic calculators, graphing calculators, technology, attitudes, motivation, satisfaction, STEM, college students, college algebra, college math,* and *college mathematics*. Much of the literature included in this review was published between 2011 and 2015, in order that the support for theory was taken from more recent findings and reports. The older literature published between 1992 and 2010 is seminal literature used in discussion of the theories originating and popularized during that period.

2. THEORETICAL FRAMEWORK:

The theoretical framework used was comprised of two prongs: constructivist theory and technology-assisted instruction theory. These theories combined to contributed to a theoretical framework that determines academic achievement by way of two main features: learning as it is constructed by the learner and learning as it is supported and enhanced by technology and both of which are supported by a balanced student-centered, constructivist teaching and learning approach and student-centered, teacher-facilitated, assistance technology instruction approach.

2.1. Constructivist theory:

The literature on constructivist theory puts forth the position that individuals seek understanding of the world in which they live and work by developing or constructing subjective meanings through viewpoints about their learning experiences and directed toward certain objects or things (Creswell, 2013). According to constructivism principles, students are self-directed and become the center of their own learning, especially when they are taking courses at the college level (Colburn, 2007; Loyens et al., 2007; Pegues, 2007; Duffy & Cunningham, 1996). Constructivism is more a theory of learning than it is a particular methodology (Simpson, 2006). Therefore, understanding the basics of constructivism can help with the idea of implementing a graphical calculator for learners to better visualize challenging and abstract topics in college algebra such as transformation on functions.

According to constructivist theory, in the college algebra classroom where a graphing calculator is a valuable tool in the understanding of the course material, the graphing calculator will contribute to the student's actual hands-on experience, for with the graphing calculator, the majority of the students are compelled to take an active role during the lectures. The students' hands-on experience, in turn, facilitates a better understanding of the topics while using this technological tool (Brown, 2010). With students who are more passive learners, the instructor encourages the establishment of student logical connections between the graphing calculator and the course's material independently, outside of class time (Abu-Naja, 2010). When the math professor attempts to teach a class such as college algebra from the student's own perspective using the graphing calculator, consistent with the constructivist approach, learning then becomes a personal matter (Simpson, 2002). Constructivism's main objective is that professors teach flexibly during lectures and possess the knowledge to stimulate students' thinking. By utilizing the constructivist approach, professors guide students to a better understanding of the basic concepts in college algebra with the aid of a graphing calculator.

2.1.1. Evidence-based literature on the constructivist approach and student performance:

The constructivist approach as a student-centered approach has been found to work best in conjunction with other, teacher-centered approaches for a preferable content-centered instruction using inquiry-based learning (McLoughlin, 2009). The critical learning outcome for students is not only getting the correct answer but also for the student to gain understanding to explain why an answer is correct from an algebraic perspective (McLoughlin, 2009). Most important, a graphical point of view is essential for students to move forward into more advanced math courses in their college program and to, therefore, achieve greater success.

This balanced approach, keeping constructivism as a main approach, has been found in the research literature to positively influence student performance.

Baylor and Ritchie (2002) investigated content acquisition and higher-order thinking (HOT) skills, obtaining measures of student performance in classrooms where teachers conducted technology-related activities. The researchers found that improved teacher technology skills in the constructivist classroom "…help facilitate improved student performance" (p. 411). Additionally, Gales and Yan (2001) investigated the impact of several constructs involved in constructivist teaching of mathematics. The researchers found that some constructs such as constructivist teachers' beliefs that mathematics is a practical, structured, and a formal guide for addressing real world situations and students' achievement had no impact on student achievement. They also found that two constructivist teachers' practices students left to work on projects where there is no immediate correct answer and students left to find real world uses for the learning content were both found to have significant impact on student achievement levels.

2.1.2. Evidence-based literature on the constructivist approach and motivation:

According to Palmer (2005), "…motivation is recognized as a crucial factor in the construction of knowledge" (p. 1854). Different teaching techniques fall under the umbrella of constructivism, but in the end, the guidance of the math professor in conjunction with the students' motivation to learn are the main ingredients that create a context for learning and understanding of mathematics in a more efficient way. The literature supports this notion of constructive learning and motivation. According to Burns (2005) and Faulkenberry and Faulkenberry (2006), regarding the value of graphing calculators, the student assimilates the algebraic concepts based on the professor's ability to teach the math class and gain student cooperation in learning with the technological aid. In addition, according to Nie and Lau (2010), constructivist instruction is a positive predictor of students' linked cognitive strategy and motivational beliefs. In a comparative study of constructivist and didactic instruction as it relates to students' cognitive, motivational, and achievement outcomes with 3,000 ninth graders from 108 classrooms in 39 secondary schools in Singapore, the researchers focused on two types of motivational beliefs students' self-efficacy and task value. They found that constructivist instruction "…was a significant positive predictor of self-efficacy…and task value" (p. 418).

2.1.3. Evidence-based literature on the constructivist approach and student satisfaction:

Student satisfaction reflects the extent to which students perceive positive experiences with, in the case of this theory, constructivist-taught classes. The research literature supports the premise that constructivist learning yields student satisfaction. For example, So and Brush (2008) conducted a more general study of constructivist-taught learning in a blended learning environment. The researchers, who investigated for student perceptions of collaborative learning in particular, found that students who had taken more online courses tended to be more satisfied than students who had taken fewer online courses; and students who perceived high levels of collaborative learning tended to be more satisfied with their online course.

In another study, Neo and Neo (2009) investigated multimedia-mediated constructivist learning to determine student satisfaction of 53 students working in collaborative, problem-solving contexts. The researchers measured for not only motivation but also surveyed for satisfaction quotients involved in student contributions to the project. They found an overall satisfaction rate of 92.5 %. And, Zhu (2012) studied two populations of online students Chinese students and Flemish students working through constructivist-taught courses. The researcher found a variety of differences, including that Chinese students reported a higher level of satisfaction with the e-learning functions, online collaboration, and peer contribution, as well as a higher level of satisfaction with the equal contribution of group members than did the Flemish students. In contrast, Flemish students reported a higher level of satisfaction with the final results of the online group work than did the Chinese students.

2.2. Technology-assisted instruction theory:

An approach that began developing in the 1970s, technology-based instructional design has evolved to include what Paquette (2014) identifies are several "paradigms…, [including the implementation of] authoring tools, expert systems and intelligent tutoring systems, automated and guided instructional design, knowledge-based design methods, eLearning standards and social/cognitive Web environments" (p. 661). The literature on technology-assisted instruction theory, in general, reveals that technology-assisted learning improves knowledge acquisition (Paquette, 2014; Hui, Hu, Clark, Tam, & Milton, 2008). For example, while they find that technology-assisted instruction is less effective for concrete experiential learning Hui et al. (2008) added that this is the case especially with learning contexts that demand abstract conceptualization and reflective observation, or, meta-cognition.

2.2.1. Evidence-based literature on the technology-assisted instruction approach in general and student motivation:

The literature on technology-assisted instruction or technology-based instructional design theory in general also supports instructional practice as it encourages and fosters student motivation. Keller (2008) studied the influence of technology-assisted instruction on student motivation. The author highlighted the emphasis of technology-assisted instruction on "effectiveness, efficiency, and engagement" (p. 175) and outlines 5 first principles of motivation that "characterize learning systems that effectively motivate students" (p. 175). These principles are prescriptive and are described by the author as motivation to learn that is promoted (a) when a student has a gap in knowledge that arouses his/her curiosity; (b) when the student perceives the new content knowledge to be relevant to his/her learning goals; (c) when the student believes it is possible to master the learning task at hand; (d) when the student anticipates and then experiences learning outcome satisfaction; and (e) when the student of his/her own volition uses strategies to persist in mastering the learning task at hand.

Gabrielle (2003) conducted studies using Keller's ARCS Model of Motivation (1999) to determine the impact of technology-mediated instructional strategies on motivation. The researcher found that technology-assisted instruction lent to increased levels of the tendency to be self-directed learners. Gabrielle (2003) also found increased scores on several of Keller's Course Interest Survey (CIS), including increases in Attention, Relevance, Confidence, and Satisfaction. Harris, Al-Bataineh, and Al-Bataineh (2016) studied the impact of one-to-one (1:1) technologies such as Pearson enVision Math series with Topic Tests on student motivation (and achievement) in Title I fourth graders in a Central Illinois school. The researchers, who measured motivation by way of attendance in the 1:1 classroom *versus* attendance in the traditional math classroom over a four-month period, found that attendance was relatively similar in the first two months, but in the second two months of the trial there were fewer absences in the 1:1 classroom than there were in the traditional classroom. The causes for the absences were not disclosed, so it is worth noting that the presence or absence of technology may not be the solitary driving factor for attendance. That is, other reasons for student absence from school not feeling well, playing hooky, taking a vacation with parents might also need to be further investigated.

Bernard (2014) investigated the effect of project-based learning (PBL) integrated with technology on motivation in an eighth-grade physics classroom. Using an Intrinsic Motivation Inventory to measure motivation, the researcher found that on a Likert-type scale of 1-5, student enjoyment was 3.65, student-perceived competence was 3.77, effort/importance was 4.00, and value/usefulness was scored 3.41. These scores, in combination with student responses to open-ended questions on the survey, led the researcher to conclude that project-based learning (PBL) integrated with technology motivated most students while increasing student knowledge of the concepts of physics "…because it was considered fun…" (p. 14), a term used by the study subjects more than 100 times. And Olsen and Chernobilsky (2016) studied the influence of technology on motivation in the middle school mathematics classroom. The researchers studied sixth graders using an online, standard-aligned practice program and found that not only did performance significantly improve for the students using the technology, but that "…students generally have a positive view of math, care about their performance, and recognize math's practical implications, and that…students were engaged and wanted to succeed" (pp. 11-12).

2.2.2. Evidence-based literature on the technology-assisted instruction approach in general and student performance:

The balanced approach that uses instructional design in constructivist instructional contexts and that is neither student-centered, nor professor-centered contributes to student understanding of certain challenging topics throughout the course and ideally, improves the rate of student progress, depth of understanding, and success in challenging courses such as the student's first college algebra course. This combination of teaching the content, incorporating much practice, and integrating the graphic calculator as a visual-checking tool, promoted student success in college algebra courses. The research supported the theory. Baylor and Ritchie (2002), who investigated content acquisition and HOT skills by obtaining measures of student performance in classrooms where teachers conducted technology-related activities, focused on the extent to which the use of technology added to the class performance in higher order thinking. As was noted above, the researchers found that improved teacher technology skills in the constructivist classroom "…help facilitate improved student performance" (p. 411). Rakes, Fields, and Cox (2006) conducted research that is consistent, finding that provided teachers possess the technology-related skills needed, the technology positively affects such teaching methods as those based on constructivism and therefore positively affects student learning outcomes.

2.2.3. Evidence-based literature on the technology-assisted instruction approach in general and student satisfaction:

The literature on technology-assisted instruction theory in general is also supported by the research on technology-based instruction that lends to student satisfaction. For example, Wurst, Smarkola, and Gaffney (2008) investigated the constructivist classroom in conjunction with assistive technology implemented by way of laptops to measure not only student achievement but student satisfaction. They studied both honors classrooms and traditional classrooms and found that while laptop users reported significantly less satisfaction when compared with non-laptop users, all honors students were generally satisfied with their academic education. And, in a general investigation of factors influencing student satisfaction in a technology-supported language classroom, Er, Liaw, Lim, and Marimuthu (2015) found that such factors include learner-content interaction, learner to instructor interaction, learner to learner interaction, and learner to technology interaction. The researchers also acknowledged that just as these factors contribute to satisfaction so does satisfaction have a carryover effect on student achievement.

2.2.4. Evidence-based literature on the use of graphic calculators in the math classroom in particular:

The literature on the use of graphic calculators and their application into the math classroom in particular reveals curriculum applications that deal with (a) the way some professors implement the use of the graphic calculator, and (b) how students benefit from the advantages these devices provide to support the learning of mathematics. The research focused on these centers on classroom phenomena whereby the graphic calculator or computer software programs play a major role in helping students develop a better understanding of some math concepts in advanced or basic math courses and in helping students prepare and pass college entrance examinations. This body of research yielded five sub-themes: (a) the importance of technology in teaching mathematics; (b) instructors' reluctance in using the graphic calculator, despite its successful applications in the classroom; (c) the successful implementation of graphic calculators outside the US; (d) the successful implementation of graphic calculators inside the US, in high schools and in colleges/universities; and (e) students' attitudes about mathematics and graphic calculators.

3. REVIEW OF THE LITERATURE:

3.1. The Importance of Technology in Teaching Mathematics:

Technology is important in teaching math successfully, as revealed in the next three articles. There is a significant lack of applications of technology in most math courses offered in U.S. colleges. When external tools such as the graphic calculator are used in the classroom, students can excel in math. Leng (2011) concluded that technology was used successfully at a secondary school in Singapore where students learned calculus, and professors and students benefited from its use. Students realized the importance of using technology, and they learned the subject much better when it was implemented.

The integration of technology also increased the confidence of the students. Gningue, Menil, and Fuchs (2014) employed a narrowed concept of technology to determine whether technology tools in a public community college remedial algebra course would yield better student outcomes. The authors concluded that the usage of virtual manipulatives in the classroom helped students gain a better understanding of math concepts. The classrooms infused with technology resulted in better collaborative work and allowed the class to be more student-centered. Students were more motivated to go online and practice on their own; without technology in the classroom, participants were more likely to struggle to understand course concepts. Participants in the technology-infused classroom were more likely to have more confidence in doing math than their counterparts in non-technology infused classrooms.

In another study, Porter, Ofodile, and Carthon (2015) investigated the impact on students' attitudes and achievement in a redesigned college algebra course at a large public university. The course was changed from a traditional, lecture-based method to a course that combined a mandatory lab component and technology in the classroom. They concluded that students in the redesigned course had a better passing rate and higher levels of achievement than students who took the traditional course. Additionally, students in the redesigned course had better outcomes regarding passing rates and course performance than students previously taught by the same faculty member. The authors concluded that the introduction of technology in a college algebra course made a big difference in terms of student outcomes.

Similarly, Foshee, Elliott, and Atkinson (2016) found that regarding students taking a remedial, non-credit bearing college mathematics course, a course that used technology led to increased mastery of course concepts. Students also reported higher levels of self-efficacy in beliefs of their own competence in math, and 75% of the students were eligible to take a credit-bearing college-level math course at the conclusion of the course. All participants in the study, numbering more than 2,800 at a state community college used an online, self-paced course enhancement that included video lectures and practice activities. Students had to demonstrate mastery of a particular concept or skill before they progressed to the next concept or skill. Compared with their counterparts in a previous semester, the students who had the technology enhancement performed better and had better self-concepts. In particular, their feelings about their ability in math improved, as students saw that the online instruction better matched their abilities and allowed them to progress to more difficult concepts while mastering easier ones.

Another study concluded that when technology was used in a required college algebra course, students' final grades were improved (Kodippili & Senaratne, 2008). The authors divided their 72 participants into two groups of college algebra courses: one took the course with My Math Lab as an additional course component, and the other did not. The study took place at their state university. My Math Lab is a technological tool that uses multimedia instructions, tests, and homework, as well as practice exercises as an accompaniment to the traditional textbook. This online tool guides students to solving problems and learning course material. At the conclusion of the term, students enrolled in the course using My Math Lab had significantly higher course grades than those in the course without this technological tool. Additionally, the authors found that this tool freed up faculty time so that they could engage with students more frequently, and the self-paced nature of this tool suited the learning styles of many students.

The satisfaction of students also improved due to the introduction of technology in the classroom. Gleason (2012) found that when technology tools were implemented in a college algebra course, student outcomes were high, regardless of whether students were in a classroom with standard or medium-sized enrollment of 30-55 students, or a large class with an enrollment of 110-130 students. At a large public research university, two college algebra courses were studied. Whether students were enrolled in the medium- or large-sized class, they had very similar rates of passing the course and mastering course material, as well as high rates of satisfaction and engagement.

3.2. Instructors' Reluctance to Use the Graphic Calculators:

Three studies were found in the literature that show that instructors in the United States are reluctant to use the graphic calculators as a tool to promote success in college algebra or high school algebra classes. They prefer to teach math courses in the traditional way and ignore the proven benefits of graphic calculators (Abu-Naja, 2010).

The study by Abu-Naja (2010) clearly showed the acceptance of graphic calculators in a high school in Israel. Two control groups were used to investigate the effects of using the graphic calculator in the analysis of positivity and negativity of mathematical functions. The experimental group used the graphic calculator, and the control group used a traditional method lecturing by the instructor. The findings revealed that the experimental group attained a better understanding of positive and negative mathematical functions than the control group, and the students in the experimental group showed a better approach and attitude during the entire training process. A significant improvement in their thinking processes was found in the experimental group. This study emphasized the importance of using a graphic calculator in achieving gains with students in an intermediate algebra class versus the results obtained in the group that did not use the graphic calculator.

In contrast to the schools in Israel, in many colleges and universities in the U.S., the graphic calculator as an instructional technology is not always welcome, even if many of the students are enrolled in technical majors such as engineering and computer science (Beaudin & Picard, 2010). The case study, which based its research on the last ten years of use of graphic calculators, analyzed the use of TI-89 and TI-92 graphic calculators during the late '90s and then the introduction of the TI-Voyager at the beginning of the new millennium. The first two calculators (TI-89 and TI-92) were pioneers in the study of advanced trigonometry and many calculus functions. These calculators permitted the students to do a deep study of mathematical, graphical representations. The TI-Voyager introduced later was just a more advanced and improved version of its predecessors with more capabilities such as a module to do the analysis of advanced differential equations. Two different populations of math professors were analyzed and compared. The first group included professors who accepted the use of this new technology in the classroom to motivate their students to obtain a better understanding of advanced math concepts. In the second group, professors were identified as reluctant to use this new technology, and they continued to teach their courses in a traditional way, as they felt it was a more efficient method to utilize with their students.

Boggan, Harper, and Bifuh-Ambe (2009) revealed that instructors might be hesitant to use the graphic calculators because of the need to acquire in-depth training to master and teach the graphic calculator and computer software programs. U.S. elementary school teachers had a great deal to learn about the latest technologies to help students succeed in the classroom, including graphic calculators, smart boards, and other technological gadgets. If teachers succeed in mastering these tools, the researchers concluded that they served to motivate students in the learning process. Furthermore, the results showed that, when instructors applied technology into the classroom, a win-win situation occurred for all. Moreover, students felt more confident when they had to use technology in the entire learning process. This research study demonstrated that instructors must be prepared in the use of technology because they are dealing with a new generation of students who are willing to use technology for the solution of mathematical problems in their math and science classes (Boggan et al., 2009).

Hitt (2011) found that only when instructors were shown the benefits of technology were they willing to use it in their classrooms. After the researcher introduced some technological activities into the traditional lecture classrooms and instructors realized their benefits, they then supported the use of technology for improved learning outcomes. This study also demonstrated that a collaborative environment was a contributing factor in the students' positive experiences.

3.3. The Successful Implementation of Graphic Calculators Outside the U.S.:

The implementation of the graphic calculators in Great Britain, France, Malaysia, Singapore, Italy, Venezuela, the Netherlands, New Zealand, and Australia has been successful for students who are taking college entrance-level examinations. In terms of the application of these research studies to the United States, most college-entrance examinations currently prohibit the use of graphic calculators. Unfortunately, this practice is contradictory as many U.S. high schools allow students to use calculators, and this affects their performance in college level math classes when the calculator is absent.

Brown's (2010) research was centered on the introduction of the graphic calculator in three centralized examination systems located in Denmark, Australia, and students in the International Baccalaureate programs. The study results illustrated the new, higher level of mathematical skills that students needed to acquire to pass these college-entrance exams. All the new skills were based on gaining competence in the use of the graphic calculator.

In another study, Lee and McDougall (2010) concluded that measurable use of graphic calculators in the classroom gradually reduces the mechanical processing time and enhances students' abilities to construct their own learning. This study based its research in Canada on secondary school teachers' conceptions of mathematics and their teaching methods correlated with the use of graphic calculators. The graphic calculators not only increased the proficiency of students in the mathematics classroom, but it also provided extra help for students to visualize and thus better understand difficult concepts in math. The implementation of these devices is a win-win situation in any math classroom. This study based its conclusions on a tiny sample of professors. In future research studies, it would be best to target a bigger sample to reach more generalized conclusions.

Students at a private university in Malaysia experienced positive effects when they were learning probability in a math class (Tan & Tan, 2015). The study concluded that using the graphic calculator influenced the ways in which math was taught and learned. Two groups of participants were involved in the study: one studied probability using graphic calculators while the other group used a scientific calculator. At the conclusion of the study, it was noted that students who used the graphic calculator gained a better understanding of the course material and performed better on a test compared to those who just used the scientific calculator. Moreover, students increased their confidence and enjoyment of the subject and changed their perception of math to "learning Mathematics easy and fun now" (Tan & Tan, 2015, p. 21).

Also in Malaysia, Choo-Kim, Madhubala, and Siong-Hoe (2011) investigated attitudes among students who use the graphic calculator in a mathematics classroom, specifically regarding the learning of probability. Sixty-five university students participated in the study. Their attitudes about math were recorded before and after they were taught math using the graphic calculator. Significant differences were found at the end of the study. The teaching approach that uses graphic calculators increases positive attitudes and motivation about mathematics. The students also said course material was more useful in the future, said they had higher levels of interest in math, said their confidence increased, and reported they had better attitudes about collaborative learning.

At a secondary school in Singapore, a research study sought to determine whether the graphic calculator might improve the teaching and learning of calculus among 35 calculus students (Leng, 2011). The study found that unique features of graphic calculators, including multiple representations of mathematical concepts, improve the participants' ability to connect graphical and algebraic representations. Six ways that the graphic calculators were particularly useful were to explore, graph, confirm, problem solve, visualize, and calculate. Class participation also improved as did their commitment to the learning process.

Whether using graphic calculators can help improve student knowledge through signs, words, gestures and other interactions with technology was explored by Robutti (2010). In a secondary math class in Italy, the researcher used the graphic calculator and small groups to determine whether learning was enhanced by merging the private use of calculators and the public collaboration of discussion about problems. They found that the sharing knowledge through a learning community improved understanding of course material as students articulate their knowledge through class discussion using signs and gestures to demonstrate their learning.

In the Netherlands, Hoek, and Gravemeijer (2011) studied mathematics courses in a vocational education school to investigate whether students' learning style and instructors' teaching style were impacted by the use of the graphic calculator. As a result of using these calculators, instructors became more of a coach rather than a teacher as they guided students through math problems and encouraged collaboration. Calculators were used to explore and to investigate shared problems, rather than instructors showing students the entire problem. Students were able to take ownership of their own learning. Students became more collaborative as a result of using the graphic calculator. Interaction patterns used in these collaborations included generating new ideas, discussing solutions, explaining strategies, and helping group members. Classroom time was spent in more meaningful ways of understanding and collaborating hands-on, more in line with social ways of learning prioritized in 21st century workplaces, rather than individually solving problems that did not encourage this type of learning.

Handal, Cavanagh, Wood, and Petocz (2011) found that curriculum development policy and the design of other professional development programs positively influenced the introduction of technology in the classroom. The experiment took place with secondary math professors in Australia. The researchers found that a median of the professors in their study adopted the use of the graphic calculator into their classrooms in a variety of ways. The results also indicated that competence was the most significant factor in the stages of adoption and that training was the second most important factor in adoption. Moreover, personal interest was an important issue, as well as other faculty supporting the adoption of the graphic calculator. The researchers found that other factors, such as teacher's gender, teaching experience, educational qualifications, and the number of graphic calculators at each school surveyed were not statistically significant in this case study.

3.4. The Successful Implementation of Graphic Calculators Inside the U.S. in High Schools and in Colleges/Universities:

Three studies Penglase and Arnold (1996), Barton (2001), and Ellington (2006) provide meta-analyses of research studies about the successful implementation of graphic calculators inside the U.S., both on the high school and college level.

Penglase and Arnold (1996) traced the history of graphics calculator usage and the beginning of research studies on their use. They report that although these calculators were in use in the 1980s, it was not until 1990 that the first research study appeared. In their synthesis of research from 1990 to 1995 in dissertations and scholarly journals, they came to three conclusions regarding studies of these calculators regarding functions, modeling and graphing: (a) studies suggest that graphic calculators facilitate learning of graphing concepts and functions, as well as spatial visualization skills; (b) they promote exploration and investigation into mathematics among learners; and (c) they show emphasis from algebraic manipulation to graphical investigation and examination between geometric, algebraic, and graphical representations. Specifically, for students using these calculators for pre-calculus and calculus, the studies consistently concluded that students increased their understanding of graphing concepts and functions, and were better able to interpret graphical information. Additionally, studies found increased understanding among students of solving equations and modeling concepts.

Barton (2001) also performed a meta-analysis of studies on graphic calculators, focusing on overall student achievement using 46 studies that had control and experimental groups. Of the 46 studies, 29 of them concluded that the experimental group using graphic calculators had higher overall achievement than the control group who did not use these calculators; one study found that overall achievement was better in the control group, and 13 found no significant difference in achievement between the two groups.

In another meta-analysis of studies on graphic calculator use among middle school, high school and college students, Ellington (2006) found positive results across the board in 42 studies on the effectiveness of graphic calculators. Half of these studies involved college mathematics courses, while the other half involved middle or high school math courses. About 93% were in algebra or precalculus courses. Regarding the use of these calculators in the teaching of math, students benefited by improving their skill sets. These skill sets included procedural skills, conceptual skills, and these skills, combined. In terms of testing of course material, students who used graphic calculators also benefited by posting better overall scores on subsequent tests compared to those who did not use them.

Most of the research studies noted above are from many different math courses (either prep courses or very advanced math courses), but specifically in college algebra, the key course for many students to graduate from college, the research is basically nil. There is also a gap in the research for this course regarding all the variables that this research study will examine, including motivation and satisfaction. Research has been on either attitudes, satisfaction, and motivation or on achievement, rather than on all of them. This research study will add to the theory how the use of graphic calculators (specifically the TI-84 Plus and the TI-83 Plus) can benefit students in college algebra in the area of mathematical functions and its transformations and how its use will impact on the final grades of the students taking this course.

3.4.1. Use of graphic calculators in high schools:

Heller, Curtis, Jaffe, and Verboncoeur (2005) investigated the connection between student achievement in algebra and use of the graphic calculator. In Oregon and Kansas, 458 high school students from two suburban school districts participated in a test that determined whether those with access to graphic calculators performed better than those without these calculators. Results from the posttest showed that students with access to and instruction in graphic calculators scored higher than those without. The scores were even higher among those with more instructional time spent on using these calculators, and when instructors spent more time learning how to use these calculators during math instruction. The implication was that graphic calculators were successful in helping students perform in algebra, provided that enough instructional time was devoted to using these calculators, and provided that instructors received professional development in learning how to teach using graphic calculators.

Another study (Currie, 2006) suggested that graphic calculators had an especially noticeable impact on lower-ability students. This study of American students focused on students' overall grades with regard to graphic calculators. High school algebra students were put into either the control group that did not use graphic calculators or the experimental group that did. At the conclusion of the study, the experimental group scored 5 points higher than the control group on overall grades in the course, with larger improvements found among “D” or “F” students who used these calculators.

Farrell (2006) studied pre-calculus classroom at an American secondary school. When graphic calculators were used, students shifted their roles; instead of being passive, they became more active as investigators of the solution to the problem. Teachers also became more of a consultant or manager instead of being the one responsible for investigating solutions. Also, students' ability to problem solve dramatically improved when they used their calculators.

A private high school in the United States was the setting for a study from Pilipczuk (2006), who investigated the performance of students in two groups of pre-calculus classes—one that used the graphic calculator, and one that did not. Students in experimental and control groups were tested regarding their understanding in three areas: graphing, modeling, and solving problems. Although there was no significant difference found between the two groups on their ability in these three areas, the group that used graphic calculators did better on tasks that required sketching the graph of a function. Also, they were less likely to make mistakes on scaling issues and perceptual illusions when they graphed the behavior of a function. Plus, they used correct graphical methods more often than those in the control group when solving problems and were half as likely as those in the control group to provide incorrect solutions.

3.4.2 Use of graphic calculator in colleges:

The case study by Gerren (2008) of an instructor and 11 students in an American community college algebra course showed that the graphic calculator could be an effective tool in the teaching algebra. When the instructor placed the graphic calculator as the essential tool for the instructor and promoted students' independent use of this calculator, the study found that instruction was delivered at a high level, and it provided multiple representations of concepts and solutions that traditional methods of teaching algebra do not explore. Students reported that the calculator was beneficial in improving their understanding of lessons and facilitating improved course achievement. Additionally, most participants had never used the graphic calculator before but chose to use it for class tests, as they perceived that it helped them to perform optimally.

In a study of students at a community college in Florida, Muhundan (2005) focused on achievement using graphic calculators. Students were enrolled in a calculus course, and the study focused on limits and derivatives. A test on course material measured students' achievement in skills, concepts, and applications. The experimental group used graphic calculators while the control group did not. While the experimental group did not enjoy any significant difference regarding the study of limits, it did regarding the study of derivatives in terms of their skills, knowledge of concepts, and application of concepts. Also, the greatest effect occurred in problems where multiple or graphing representations were needed.

Nasari (2008) investigated calculus students at a public community college in Michigan regarding their use of graphic calculators. Students in an experimental group who did use the graphic calculator were given the same comprehensive final exam as students in the control group, who did not use these calculators. A significant difference was found in the exam in favor of those in the experimental group, who showed better knowledge of calculus concepts, due to increased ability with graphical and visual representations from their calculators. Students' overall grades in the course were higher for those in the experimental group; double the number of students in the control group either failed or dropped the course compared to those in the experimental group.

3.5 Students' attitudes about mathematics and graphic calculators:

Ellington's 2006 meta-analysis of studies on graphic calculator use among middle school, high school and college students, which was cited earlier, also examined students' attitudes. The analysis found that those who used the graphic calculator had more positive attitudes toward math compared with those who did not use the calculators. Not surprisingly, the students also expressed that they liked using these calculators while learning mathematics.

Berry, Graham, and Smith (2006) also explored the learning methods of students using graphic calculators in the United Kingdom. Students in the study stated that two factors led to decreased use of the graphic calculator. One was that graphic calculators were prohibited in some exams; only scientific calculators were allowed. Also, students were reluctant to use them on exams since they had to show all the steps required to arrive at an answer and feared that when they used the graphic calculator, all the steps would not be shown, resulting in a lower score. They also expressed positive attitudes about these calculators, stating they were helpful and that they benefited from using them. The authors concluded that educators in the UK have not been very enthusiastic about using graphic calculators, and the curriculum has changed little in the prior decade. However, with adequate training, teachers might embrace this tool in the future.

Herman (2007) echoed the sentiments of these teachers, as some negative attitudes about graphic calculators were found in this study. A sample of thirty-eight students in an advanced algebra course at a large public university participated in the study. The course required the use of the graphic calculator. Students in the study continued not to use the graphic calculator to solve problems, despite extensive training in its use. They felt that using this calculator was a form of cheating and worried about becoming too dependent on it to solve problems. They were not convinced that it efficiently helped them learn; moreover, they felt overwhelmed by having to take the time to learn how to use this tool in addition to learning course material, and it was not an important aspect of learning content in algebra. As for their positive comments, they found that graphic calculators benefited them regarding double-checking answers. Also, they saw its flexibility in being another method of solving problems as an asset. A better understanding of math was the outcome of using graphic calculators for these students.

Gogus (2006) explored perceptions of two groups of teachers who taught advanced mathematics in three New York high schools. One group was enthusiastic about using these calculators in its classroom, while the other group was wary about its overuse or misuse. Several factors impacted whether teachers used graphics calculators, including students' motivation and basic math skills, as well as teachers' expertise in using these calculators.

In another similar study, Gogus (2008) found in his small study of thirteen teachers in three school districts in New York that graphic calculators were a positive addition to the mathematics classroom. They provided a positive visual aid for problem solving and make math less time-intensive. It presented alternative methods for solutions and allows students to make algebraic connections. Overall, for these teachers, it helped students understand math better. However, if not used correctly, several negative effects can occur. Most of the teachers expressed concern regarding the overuse of graphic calculators, stating that students relied too heavily on them, even using it for basic concepts. Its expense can be burdensome for some students, as the high cost can be a detriment. Also, students used the calculators to do off-task activities or used them to cheat by storing test answers on them. The author concluded that with proper training, teachers could learn to overcome some of the negative aspects of this tool so that their students could enjoy the positive aspects.

Hatem (2010) explored the usage of graphic calculators into college algebra and pre-calculus courses at a state university in Massachusetts. Students were divided into control and experimental groups, with only students in the experimental groups having the use of graphic calculators. Pre-and post-tests were administered to both groups, and students participated in surveys that examined their attitudes. The study concluded that those in the experimental group felt that they improved in their ability to problem solve. In other words, students perceived that their problem-solving skills improved due to having access to and usage of graphic calculators. This played a role in their attitude and motivation. Additionally, they showed an increase in their interest in math classes.

Diperna (2006) examined research studies regarding factors that enhance learning environments and applied that knowledge to graphic calculators. Based on his research, he found that four key factors determine academic achievement: motivation, engagement, social skills, and study skills. Using graphic calculators can improve two of these key factors: motivation and engagement.

Tan, Harji, and Lau (2011) investigated attitudes about graphic calculators in a probability course at a university in Malaysia. Two groups of 65 students—32 in the experimental group and 33 in the control group were surveyed regarding their beliefs and perceptions about probability. Their responses were analyzed in terms of their attitudes about usefulness, interest, and self-concept. The study concluded that when the graphic calculator was used in the classroom, improved attitudes were the result. Participants developed greater confidence in solving problems and appreciated the usefulness of probability. They had increased interest and confidence in their ability in the subject compared to their counterparts in the control group, and found it overwhelmingly more useful than students in the control group, indicating they found it relevant to their daily lives.

Ha (2008) examined two Advanced Placement math courses in a high school in Hawaii, focusing on what students though about integrating technology, specifically graphic calculators, in their classes. Graphic calculators were used extensively. Based on results from questionnaires and observations, the study concluded that these calculators helped them learn math by visualizing the abstract concepts and retaining the information longer. Also, basic calculations could be performed more quickly and accurately. They felt they learned more effectively since they did not have to remember detailed steps; only the correct options on the calculator needed to be remembered to perform various calculations. Plus, the student believed that mathematical equations could be manipulated more easily when they used these calculators, and that flexibility helped them comprehend the problems better. Finally, they believed that these calculators helped them check and confirm their solutions more quickly and allowed them to experiment with math concepts to arrive at their own conclusions.

High school students in Minnesota in a functions, statistics, and trigonometry class taught with a graphic calculator were compared with students in the same course without a graphic calculator, to determine whether attitudes were different (Schrupp, 2007). Both classes were taught to solve quadratic equations by factoring, using tables, graphing, and using the quadratic formula. Both classes were given a pre-test and post-test designed to measure their attitudes about math, as well as the value of math in society, enjoyment of math, and motivation in math. A significant difference was found in favor of students who used the graphic calculator compared to those who did not regarding these areas. Specifically, the study found that these calculators allowed students to see the usefulness of math in society as well as its value. Plus, students who used these calculators experience higher levels of motivation and tend to enjoy math more.

4. SUMMARY:

The United States, as a leader in many disciplines such as politics, economics, and social sciences during the last decades, is still facing some difficulties in the teaching and learning of mathematics across many of its colleges and universities (Dewey et al., 2009). These problems begin in basic entry mathematics courses such as college algebra (Dewey et al., 2009). College algebra, as a first college level course that is mandatory for the majority of students, combines a deeper knowledge of algebraic concepts with a strong assimilation of the graphical representation of functions. It is at this point that the graphic calculator played an essential role in this research project.

The theoretical literature focused on the constructivist perspective and on technology assisted learning supports this in general. And in particular, the research-based literature focused on constructivist approaches, technology-based instructional approaches, and a combination of balanced or blended learning factors support the use of technologies such as the graphics calculator for improving student motivation, performance, and course satisfaction. There is no best way to teach mathematics at the college level, but using the capabilities of a graphic calculator to better understand difficult concepts in college algebra, such as transformations on functions, is essential for many students and marks the difference between failing and passing this challenging course (Dewey et al., 2009). The importance of using a graphic calculator to better understand mathematics is supported by research and data compiled from around the globe. Also, college algebra students must not only learn mathematical skills but also be capable of applying and better understanding these skills in real life situations while using a graphic calculator. Moreover, they must quickly adapt to a very fast-paced, dynamic technological environment, not only at home, but around the world. This literature review identified the theoretical framework used in this study, comprised of two prongs: constructivist theory and technology-assisted instruction theory. This chapter then reviewed the research supporting and/or reinforcing each theory as it addresses student performance, student motivation, and student satisfaction.

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